Hybrid Systems Research

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Hybrid systems are dynamic systems in which discrete and continuous behaviors coexist and interact. Broadly speaking, they are systems in which change occurs in response to events that take place discretely, asynchronously, and sometimes non-deterministically and also in response to dynamics that represent causal evolution as described by differential and difference equations of time. Often, as shown in the figure, a given system may be represented as a parallel composition of simpler hybrid systems. Each such subsystem is represented by an automaton with discrete states and events. Each discrete state supports a continuous multidimensional state space, shown as a fiber in the figure, on which the system evolves according to a given state equation defined on states, controls, and disturbances. Conditions on a fiber, such as departure from normal operation represented as a subset of the state space, may cause discrete state transitions. Certain of the discrete states are designated as unsafe states. The two primary concerns are system safety and system liveness. A hybrid system is safe if it visits only safe states. It is lively if it performs its intended function.

The objective of the research is to develop, in collaboration with the universities, a rigorous theory for the design and analysis of hybrid systems. The focus of the research has been on the combined system comprising an aircraft, cockpit, and pilot. The continuous part in this case describes aircraft motion including translation, rotation, aerodynamics, and power, requiring all together at least a 14-dimensional state space. The autopilot, with its control modes and the control panel, determines the discrete part of the system.

The concept of minimally restrictive legal controllers has been developed. Such controllers enforce safety with the fewest restrictions on liveness. Algorithms for the design of minimally restrictive legal controllers have been developed for a class of hybrid systems.

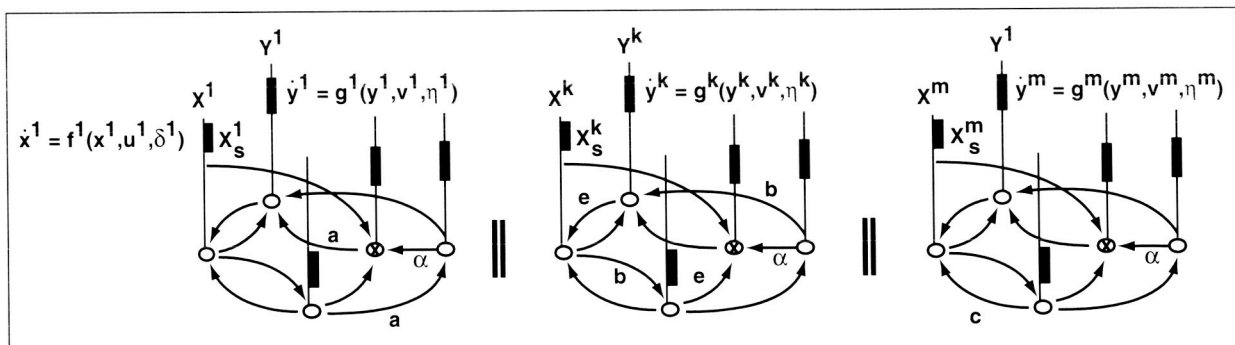**Point of Contact: G. Meyer**
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Fig. 1. Model of hybrid systems.